The Deep Space Network as a Science Instrument

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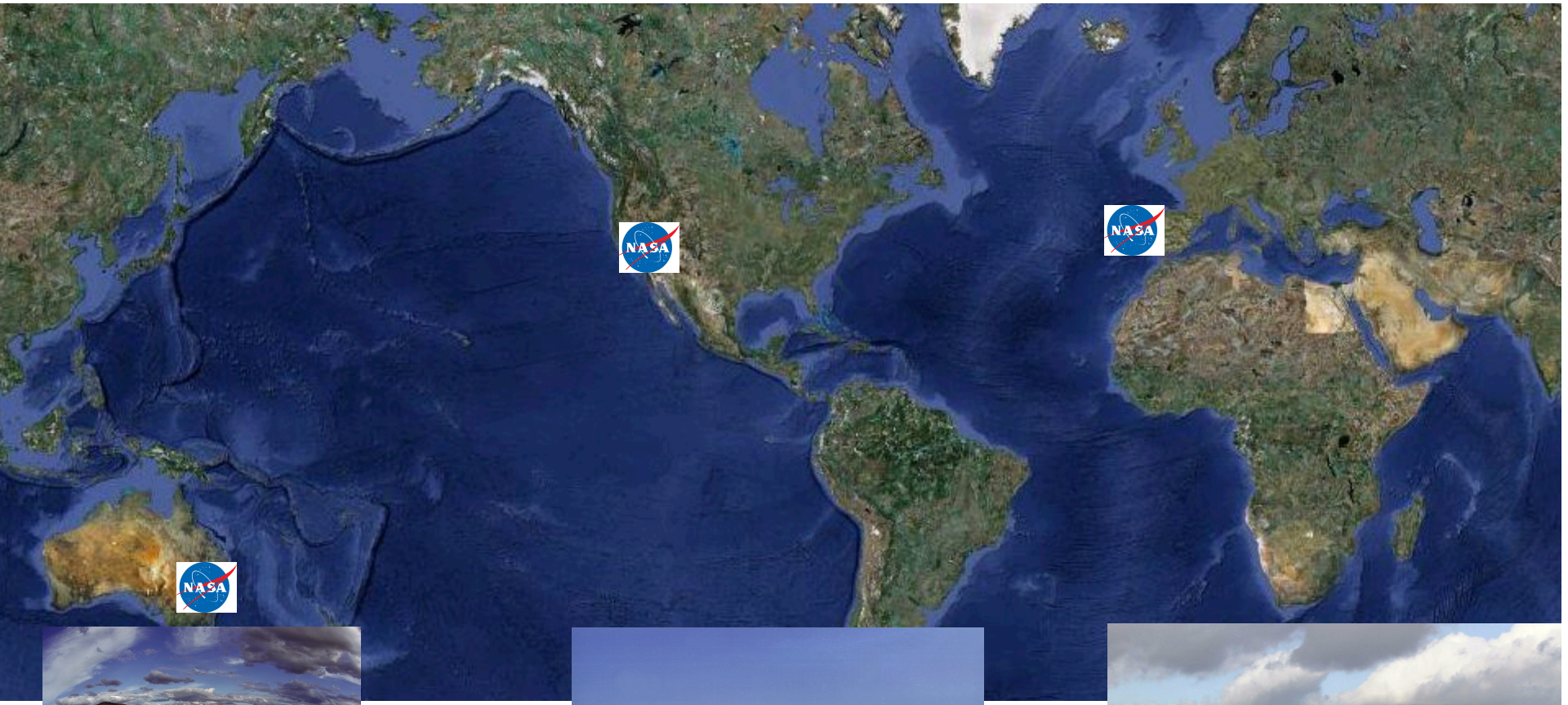
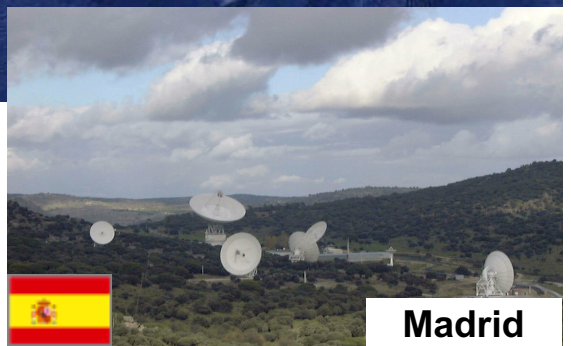
Deep Space Network



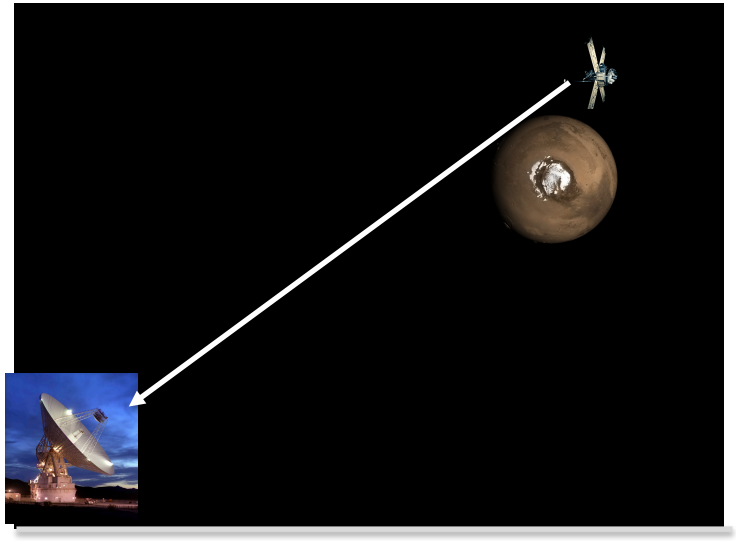
Canberra

Goldstone



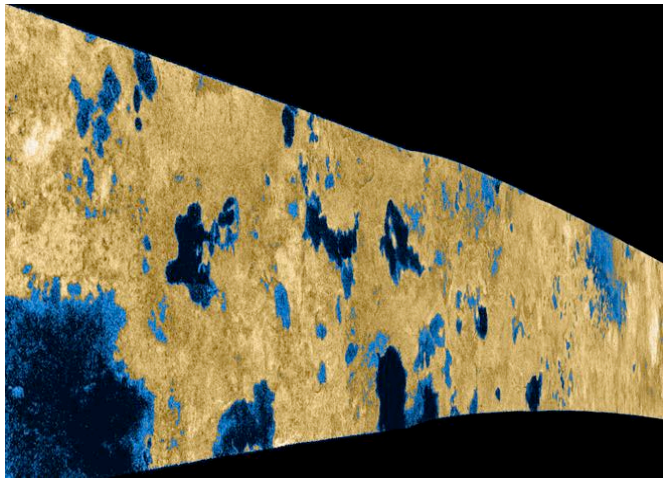
Madrid

Science done with the DSN:

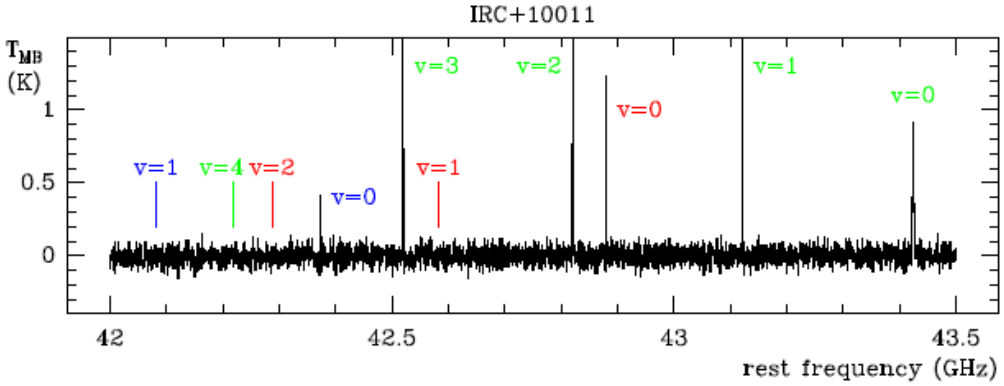


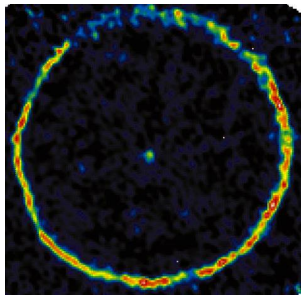
Radio Science

Planetary Radar



Radio Astronomy



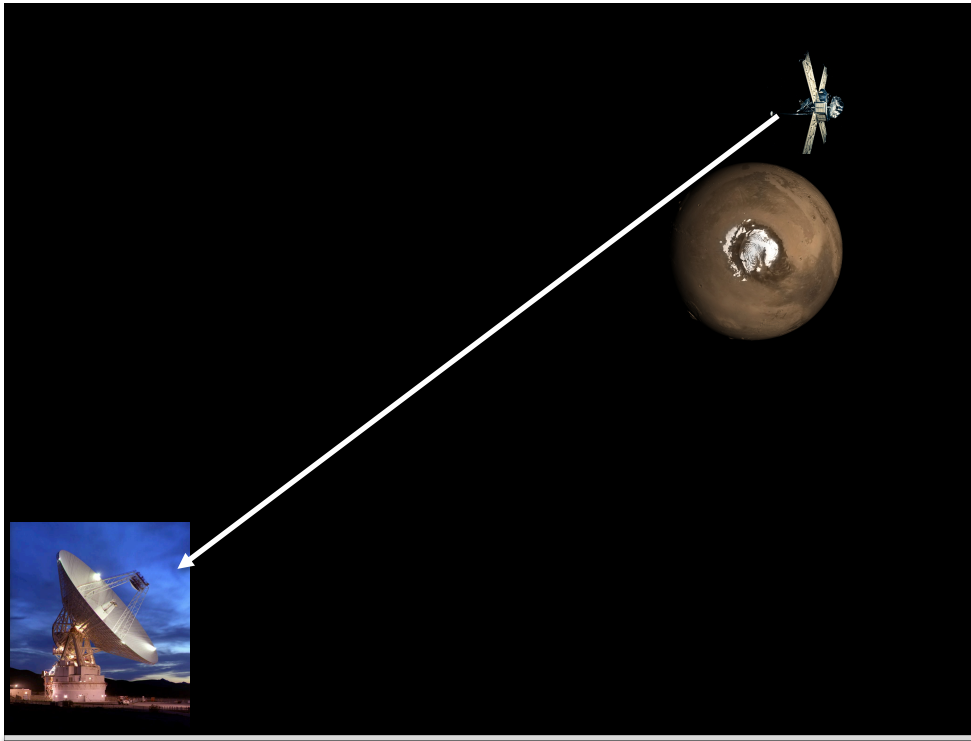


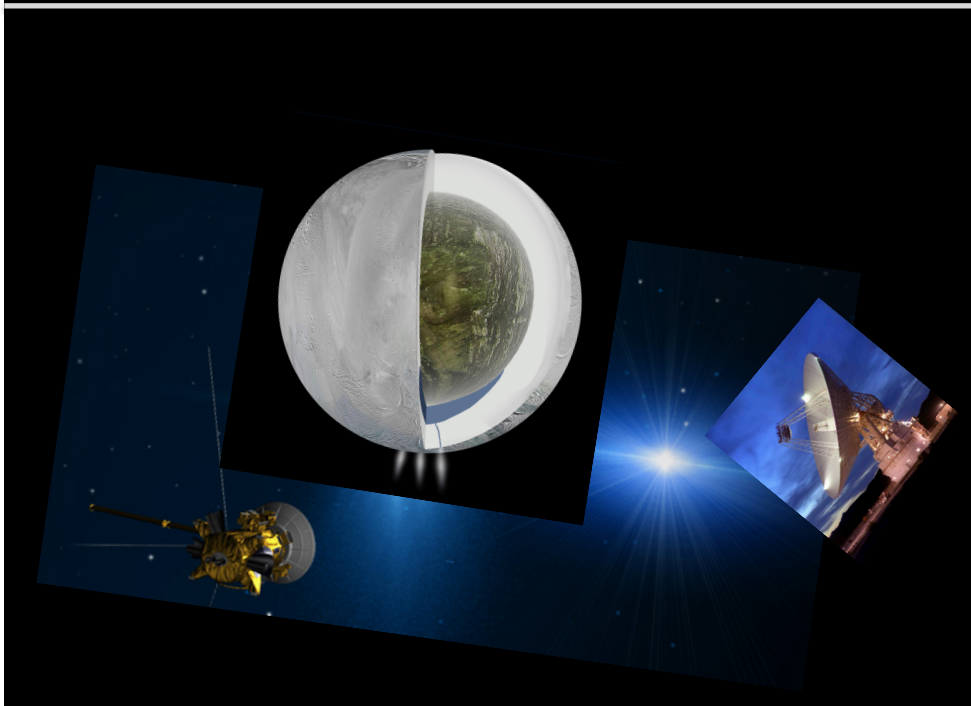
Radio Science History

Apparent even with early missions that occultations by planetary atmospheres would affect radio communications

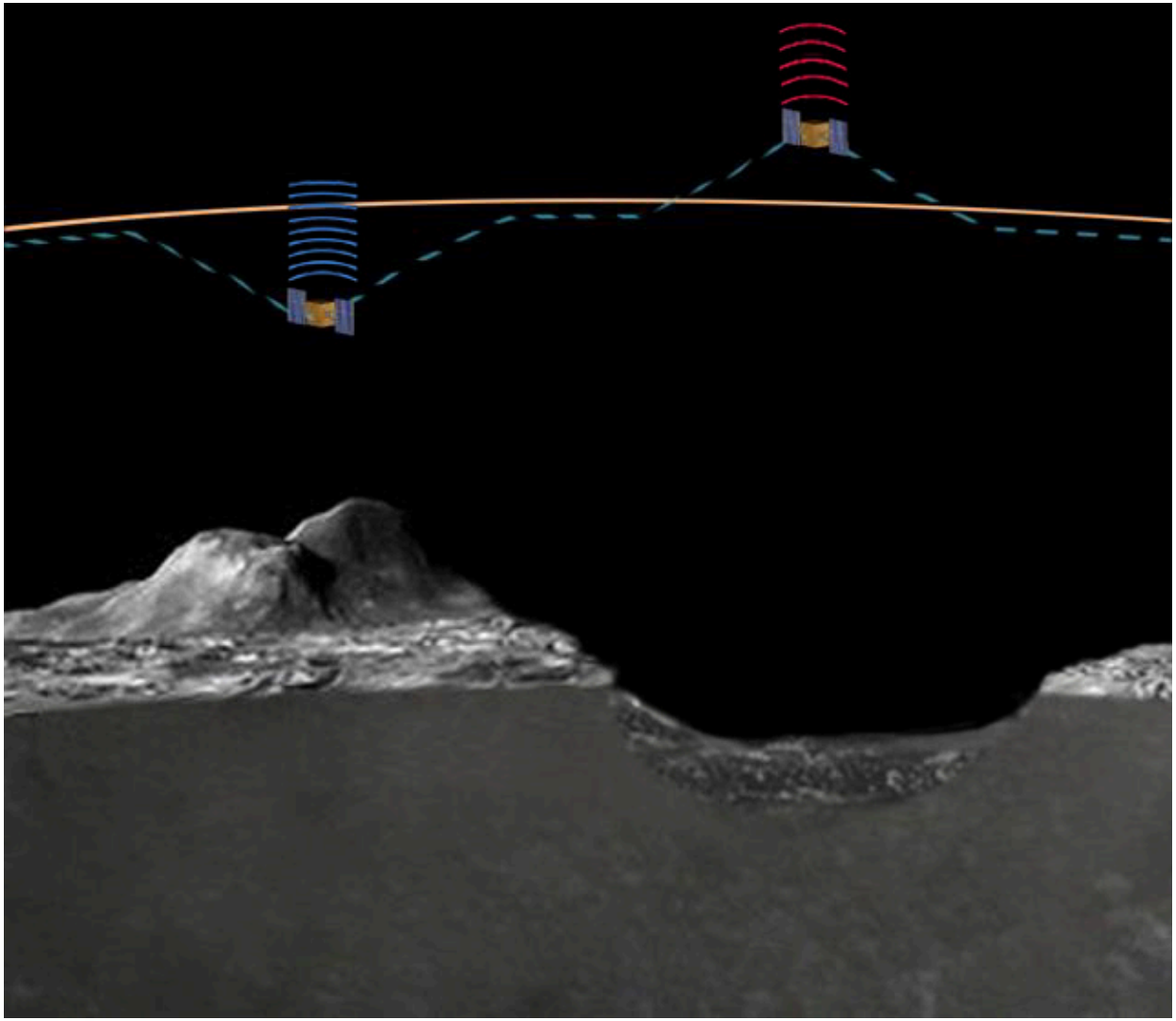
- **Tragedy!**
- **Or one person's annoyance is another's data --- Study atmospheric properties!**
  - **"Occultation Experiment: Results of the First Direct Measurement of Mars's Atmosphere and Ionosphere" (Kliore et al. 1965, *Science*)**
- **Can also study planetary interior!**

➢ **Turn the DSN+spacecraft into one giant science instrument**

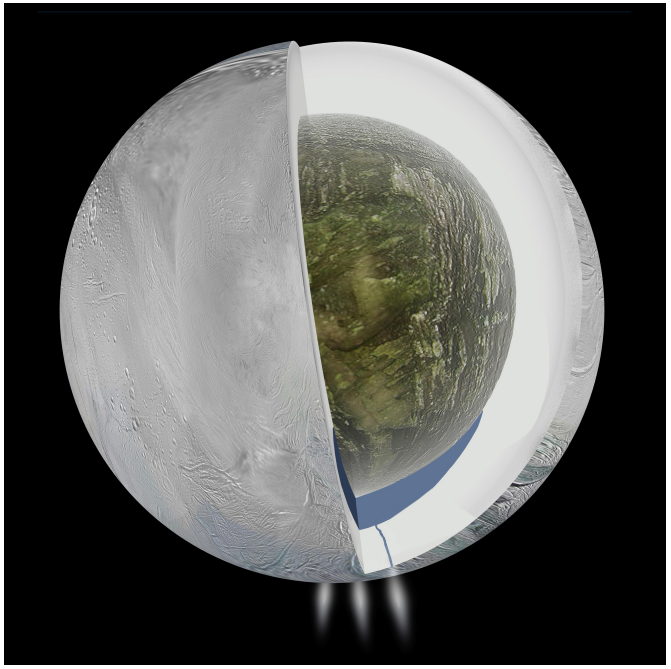


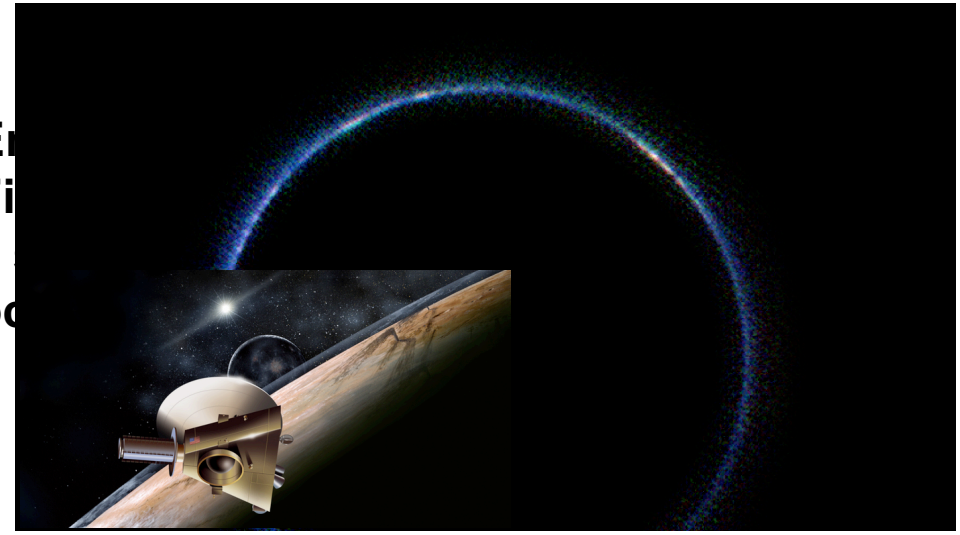


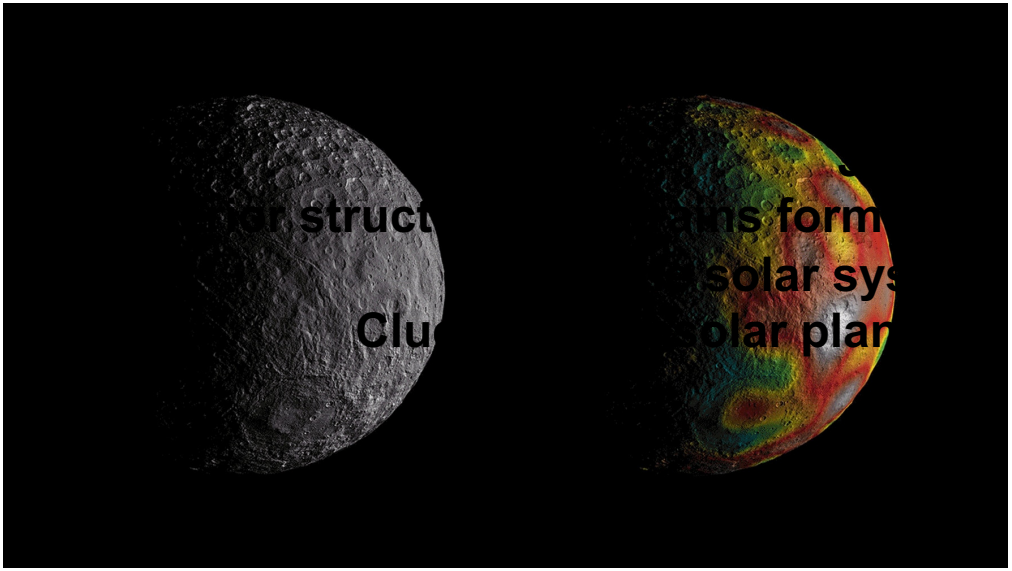
Radio Science – How it works

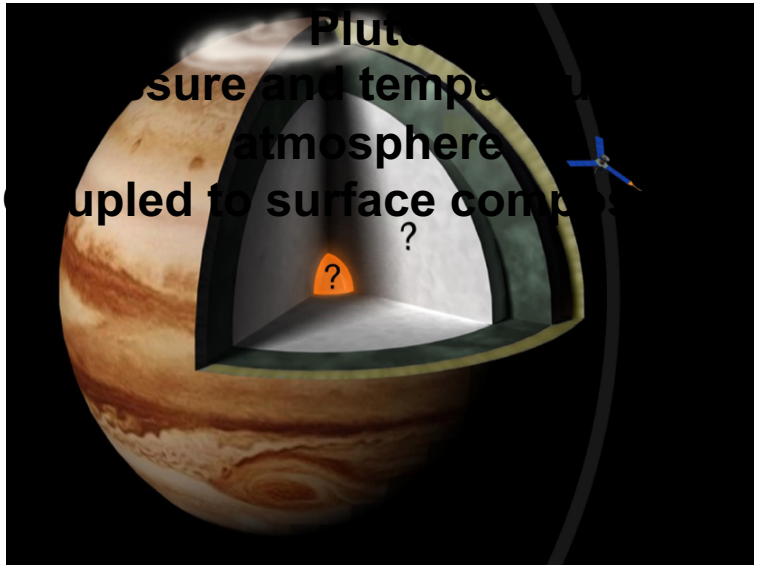


Radio Science in the Solar System Today

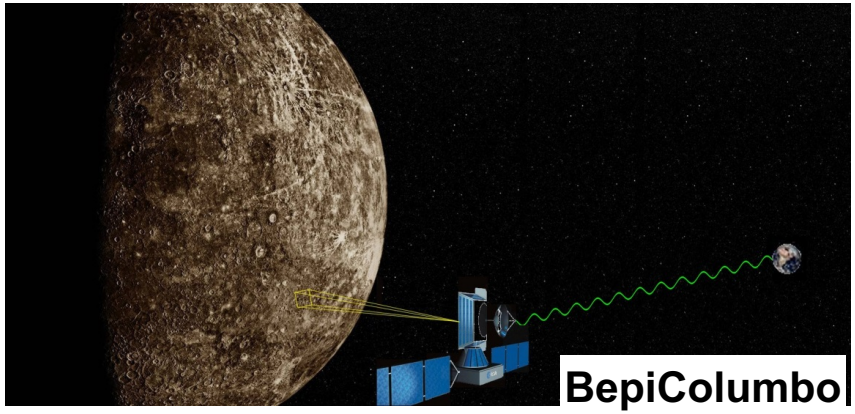






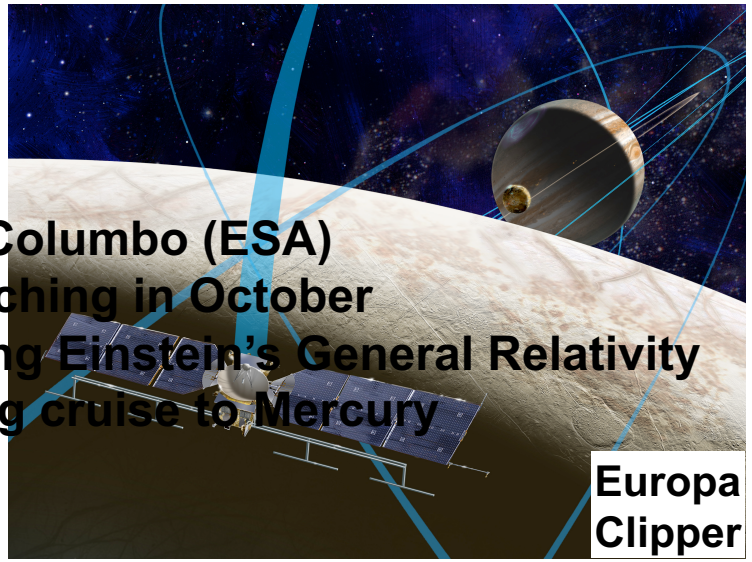


Radio Science in the Future



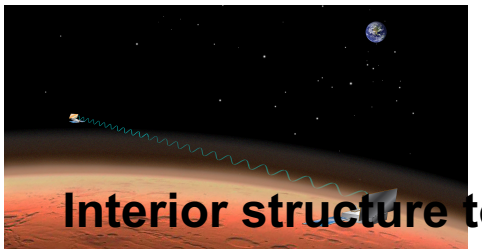
BepiColumbo

BepiColumbo (ESA)
Launching in October
Testing Einstein's General Relativity during cruise to Mercury

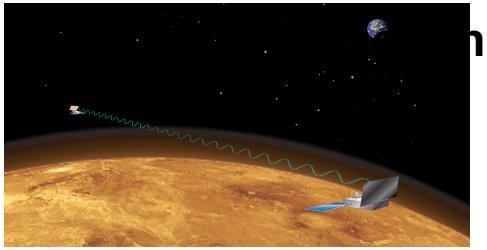


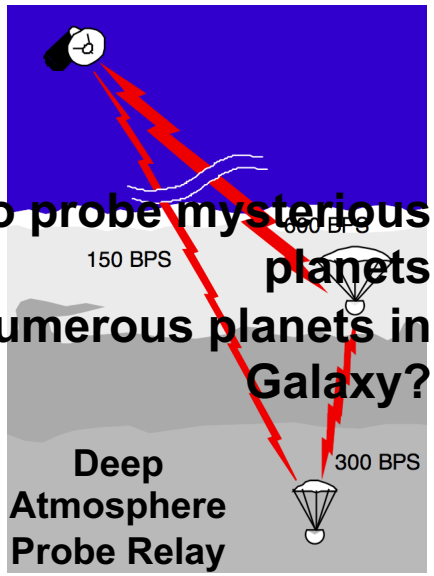
Europa Clipper

Launching in early 2020s
Probing the structure of

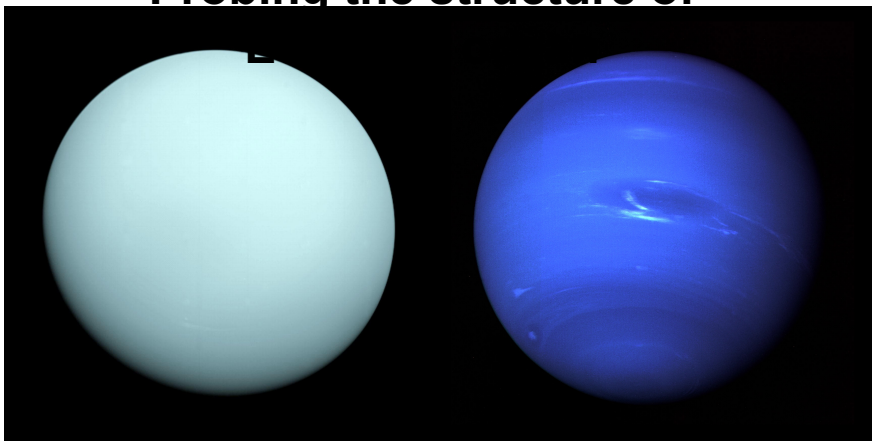


Interior structure to probe mysterious planets



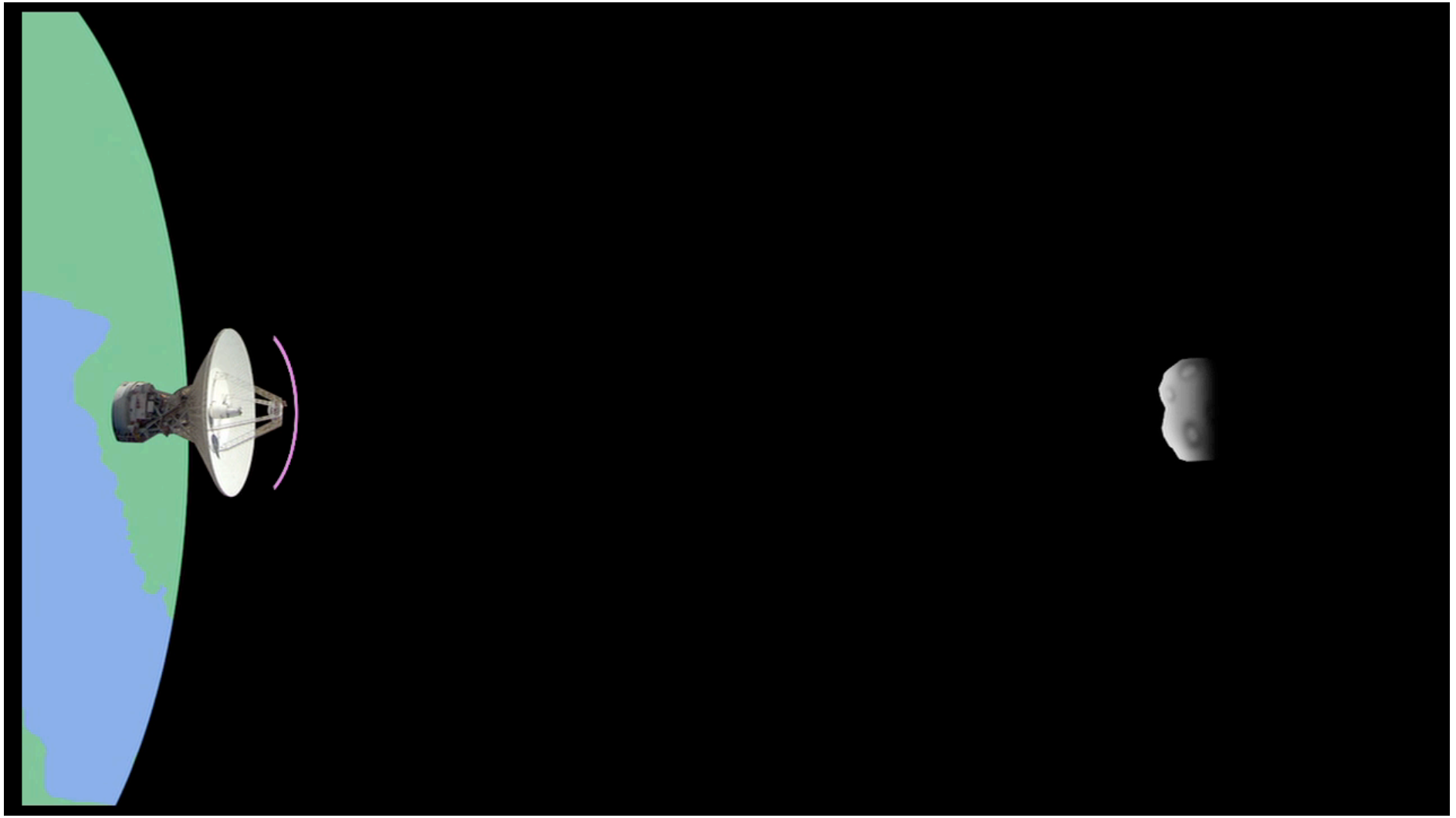


numerous planets in Galaxy?



Ice Giant Mission Concept

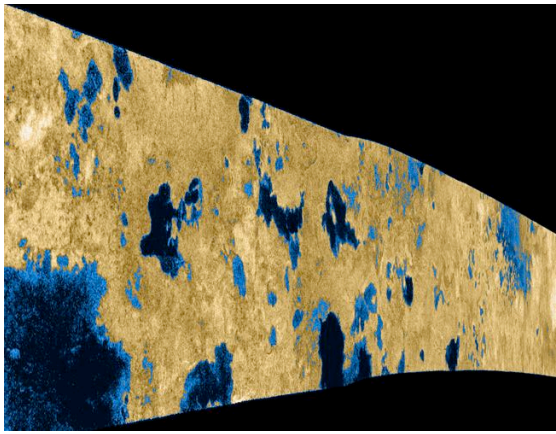
Radar with the DSN



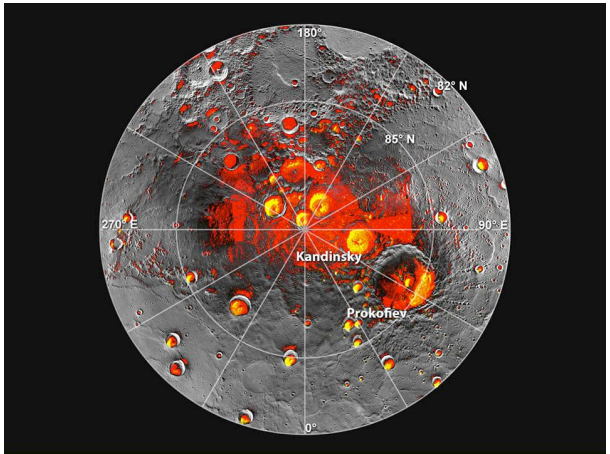
DSN Radar Accomplishments

- First indications of Venus retrograde rotation (1962)
- Probing the surfaces of asteroids (1976)
- First radar returns from Titan (1989-1993), suggestive of icy surface but with potential liquids
- Anomalous reflections from Mercury (1991), indicative of polar ice

Magellan radar image of Venus
(NASA/Caltech/JPL)



Cassini radar image of Titan
(NASA/JPL/USGS)

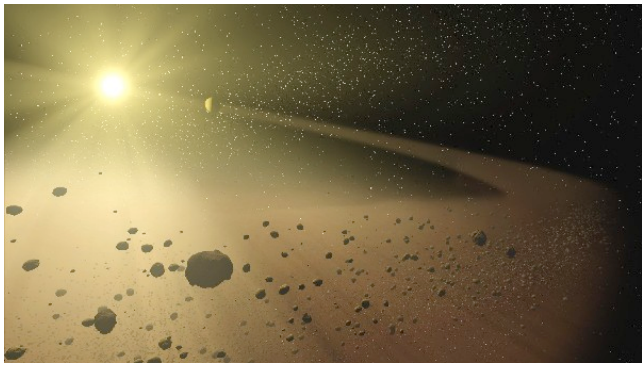


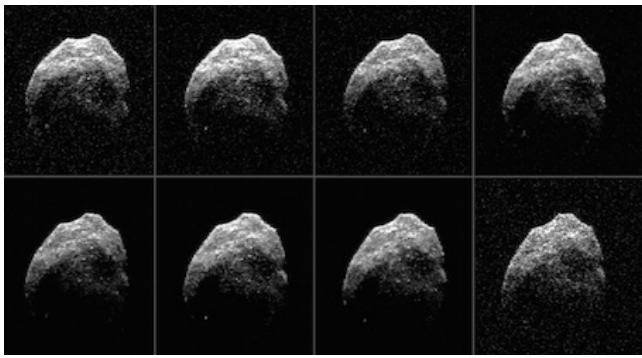
MESSENGER+radar image of Mercury
(NASA/HU APL/CIW/NAIC)

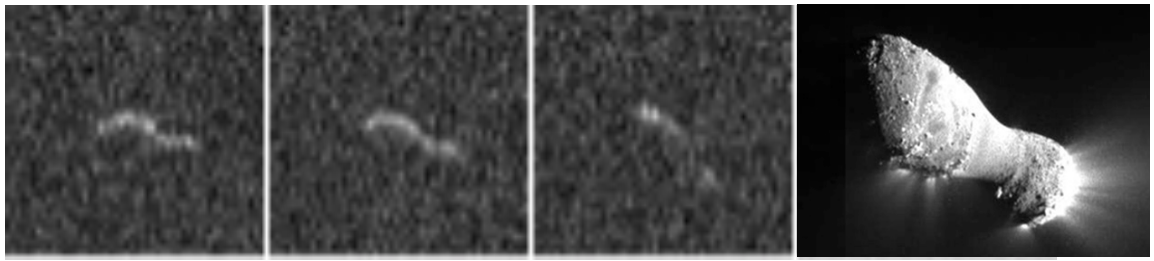
Radar Observations of Asteroids

Radar delivers size, rotation, shape, density, surface features, precise orbit, non-gravitational forces, presence of satellites, mass, …

- **Science:** Decipher the record in primitive bodies of epochs and processes not obtainable elsewhere
- **Robotic or crewed missions**: Navigation, orbit planning, and observations
- **Planetary defense**: Orbit determination for hazard assessment







About 15% of near-Earth asteroids are binaries

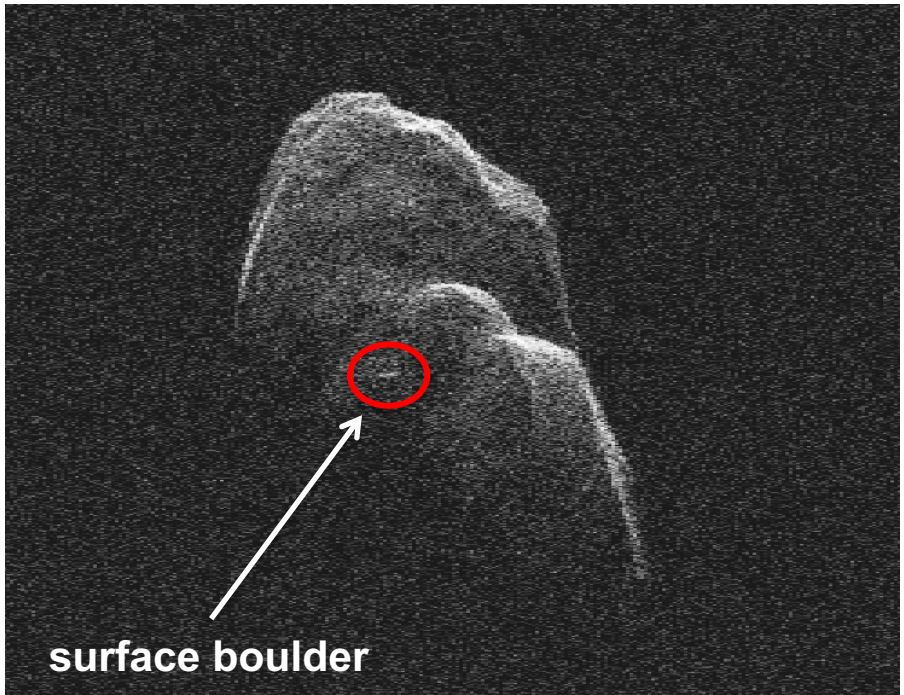
Almost all identified from radar

Radar Imaging Example

Toutatis

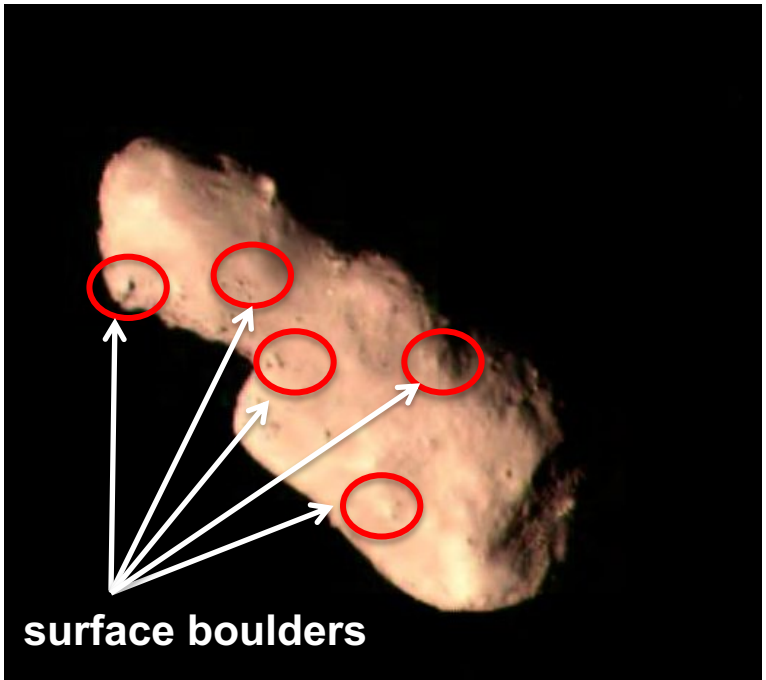
DSN's DSS-14

- 3.75 m resolution, 7 million km away
- ~65 hr of radar observations (13 hr with 3.75 m resolution)



Chang'e 2 spacecraft

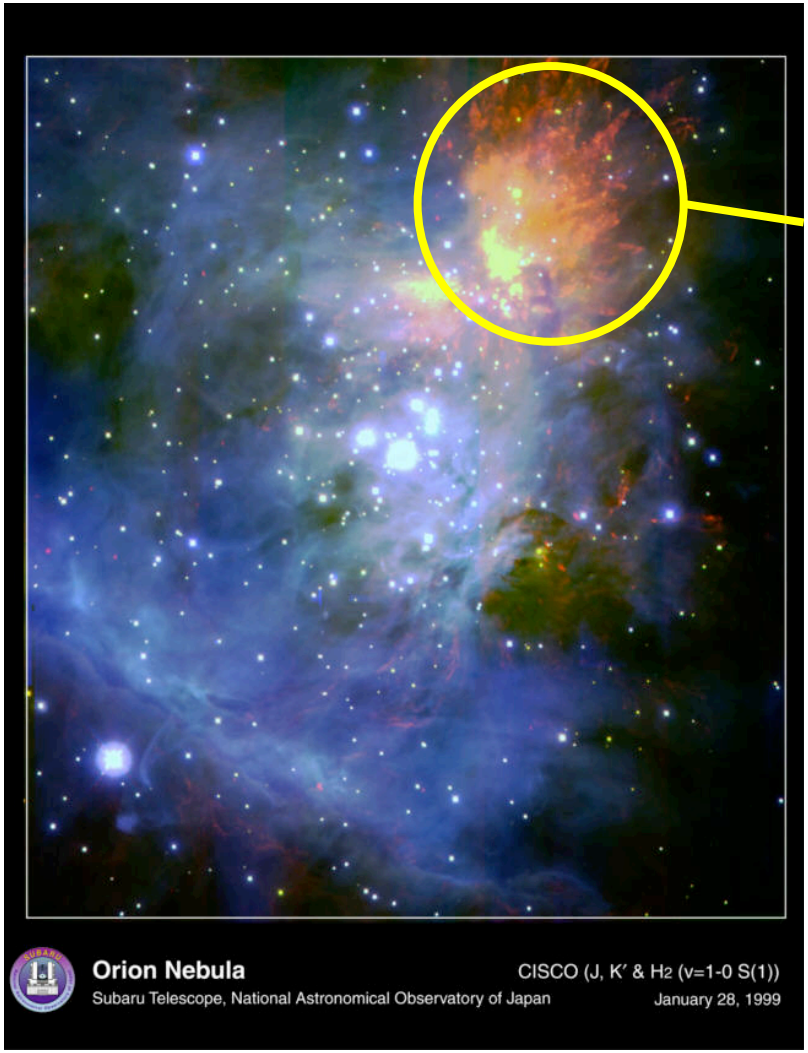
- 8 m resolution, closest image at 18.3 km away (2 m resolution)
- 15 seconds of high-resolution data

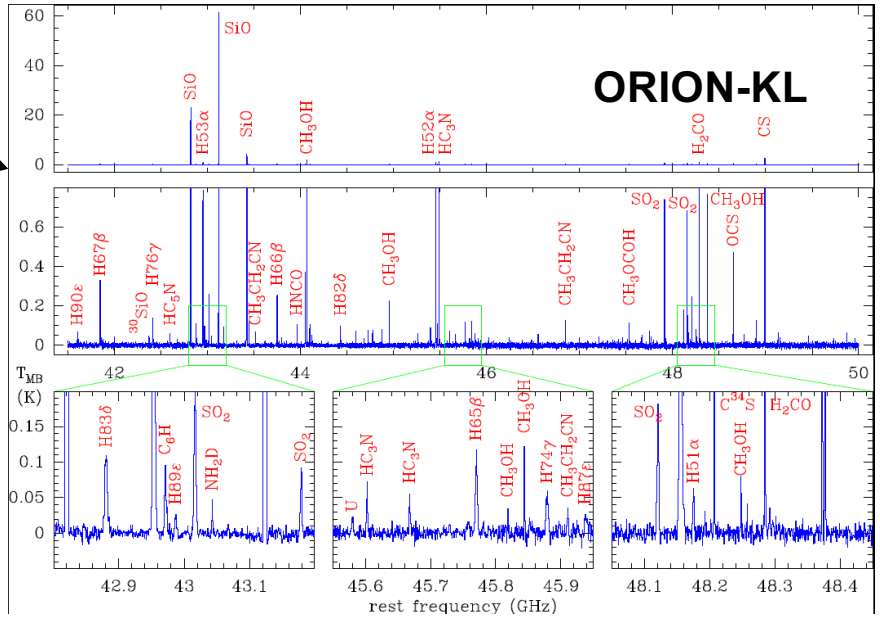


Radio Astronomy - Exploring Stars

Orion Nebula

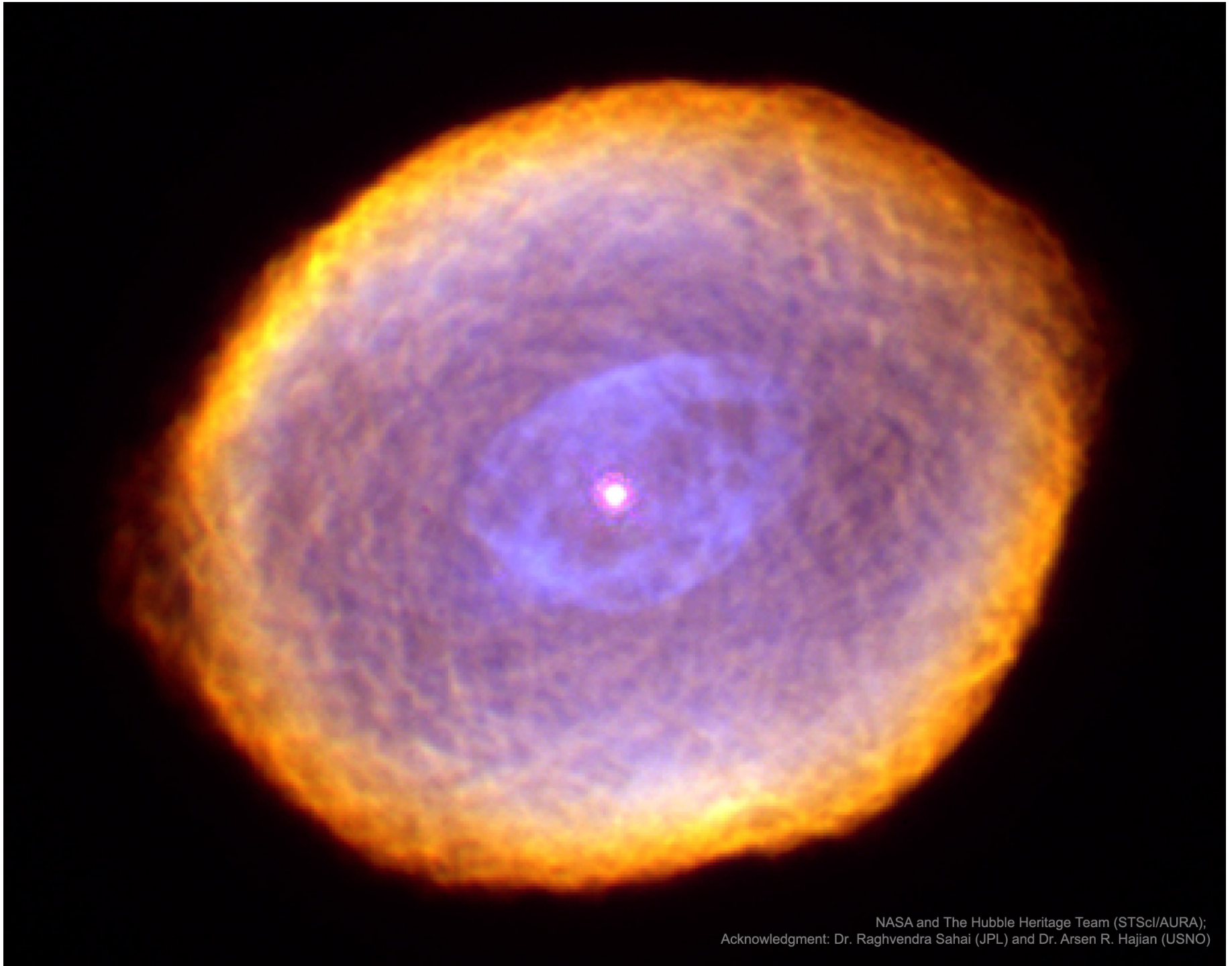
MDSCC Host Country project





***Rizzo et al.*, "The line emission of Orion-KL between 41 and 50 GHz" (*in preparation*)**

Most sensitive and widest spectrum of Orion KL between 6 and 7 mm. Obtained with Q-band receiver and wideband backend attached at DSS-54.



NASA and The Hubble Heritage Team (STScI/AURA);
Acknowledgment: Dr. Raghvendra Sahai (JPL) and Dr. Arsen R. Hajian (USNO)

Interstellar Chemistry

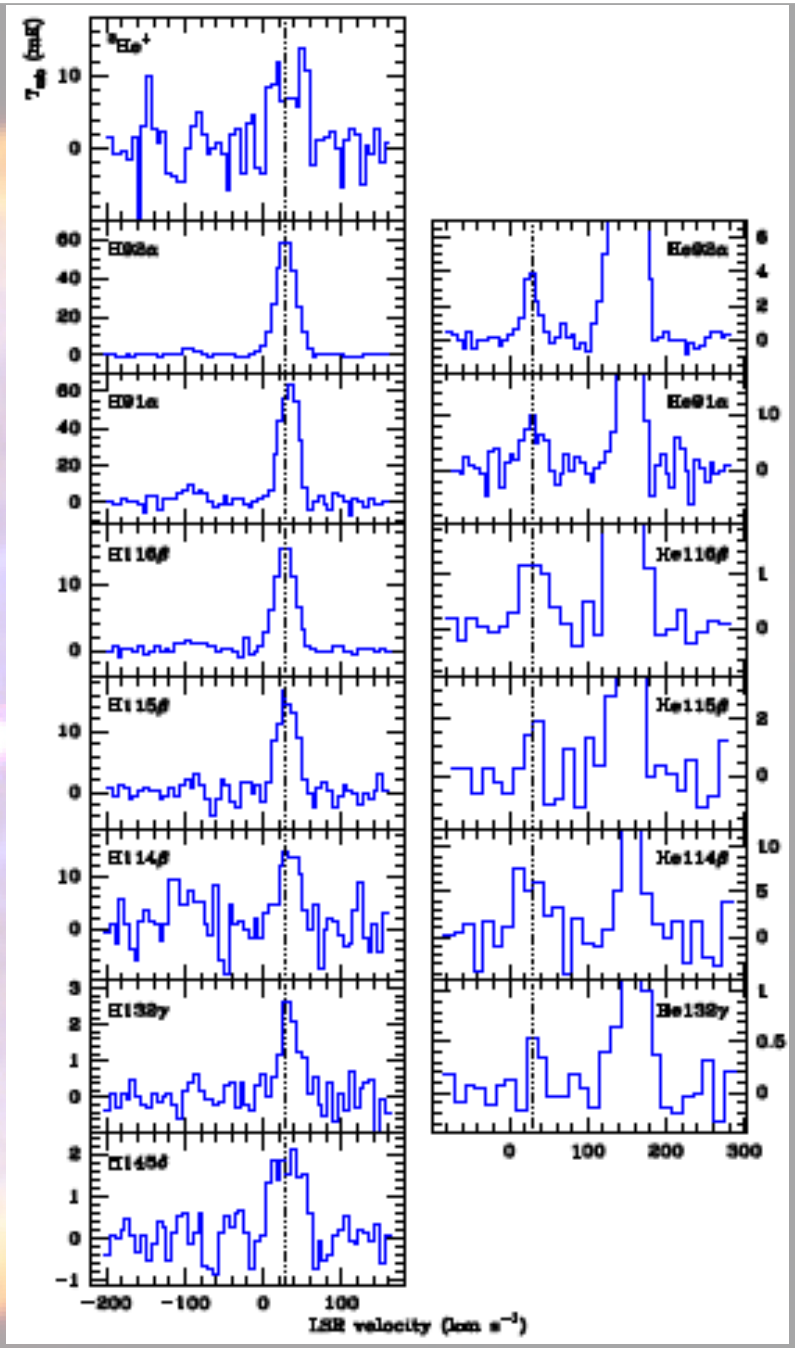
First Detection of $^3He^+$ in the Planetary Nebula IC 418

Stars like the Sun should produce lots of ^3He

Less ^3He detected than expected

- **Planetary Nebulae offer chance to check how much ^3He made by low-mass stars**
- **Only 3rd detection of $^3He^+$ in planetary nebulae**

Guzman-Ramirez et al.



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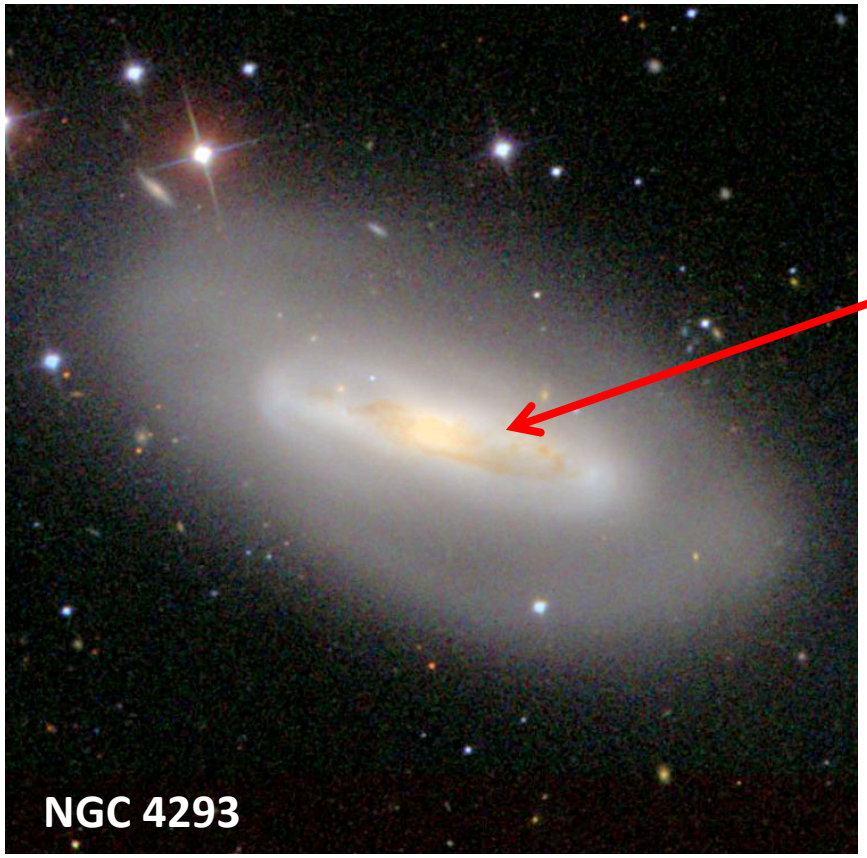
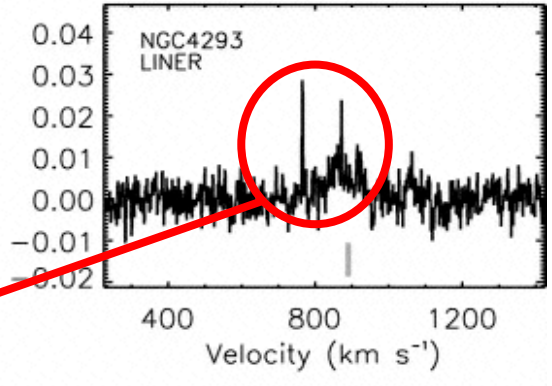
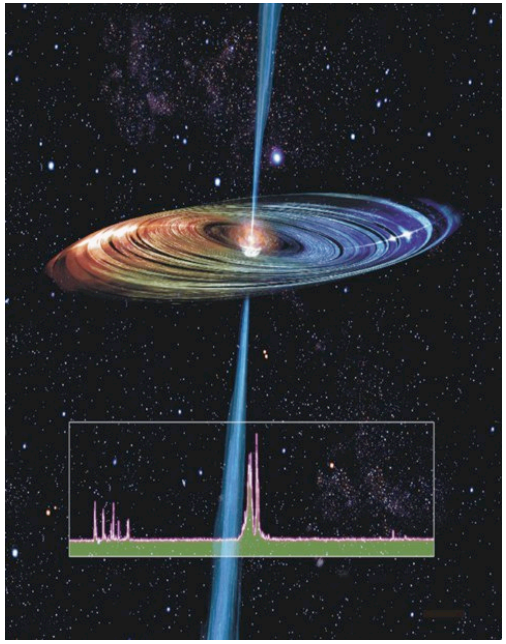
Hunting for Supermassive Black Holes

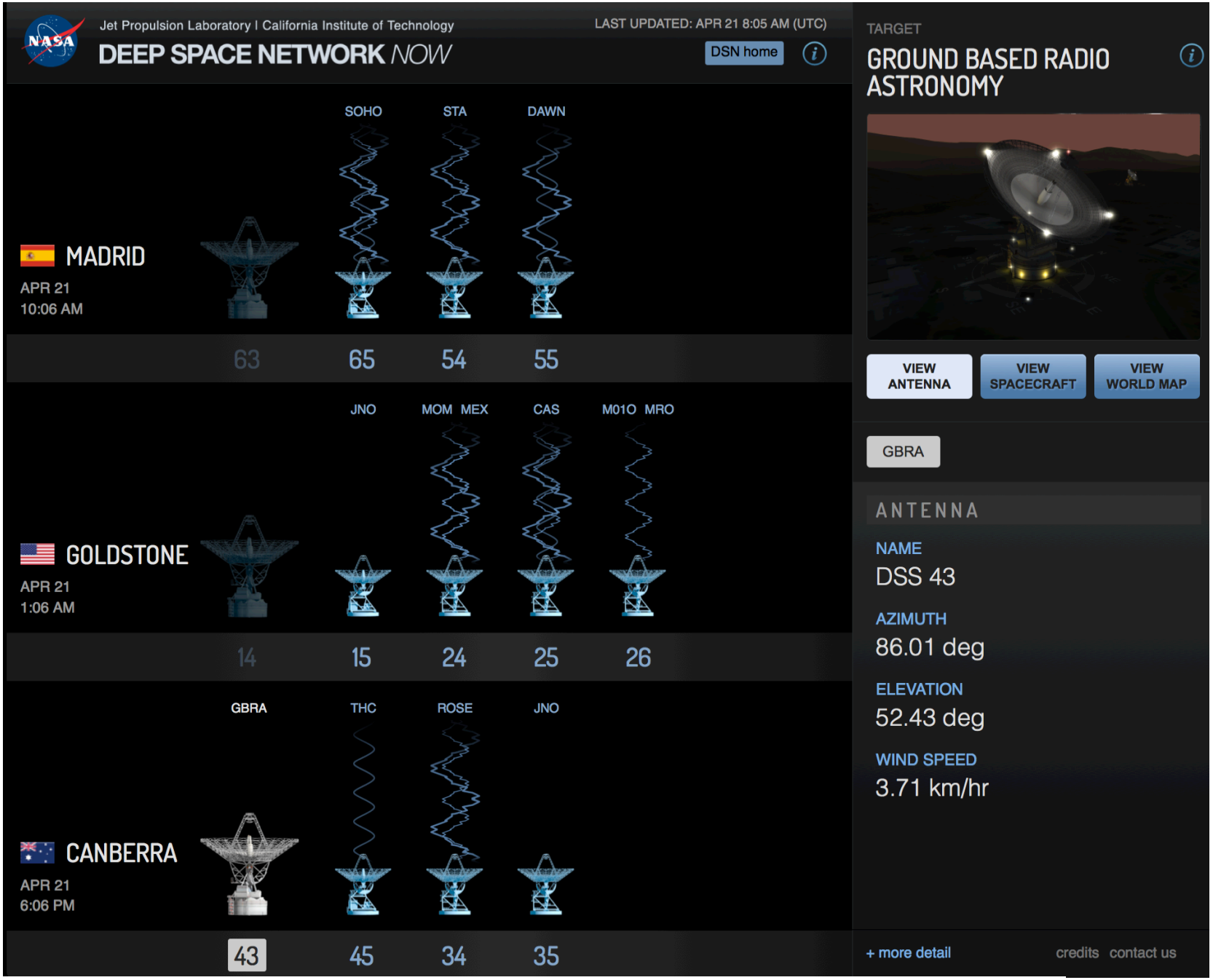
DSS-63 Survey







Kondratko, et al. "Discovery of Water Maser Emission in Eight AGNs with 70 m Antennas of NASA's Deep Space Network," ApJ, 638



http://eyes.nasa.gov/dsn/dsn.html

Deep Space Network

A Science Instrument in its Own Right!